Seismic Orbital Laser VibrometEr (SOLVE)

Completed Technology Project (2017 - 2019)

Project Introduction

The goal of our project is to develop methodology for imaging the interiors of small planetary bodies using seismic waves acquired with laser vibrometers (LV) from orbit, without landers. We will develop and prove the LV methodology, from data acquisition to 3D imaging, for determining the detailed seismic structure of comets, asteroids and small moons. This capability will allow scientists to understand a small body without the risk or cost of landing, enabling seismology as a remote sensing mission. Current knowledge of small body interiors is inferred [Binzel et al 2003; Asphaug et al 2009] and unknown in detail. Direct knowledge of internal structure will constrain theories for the origin and evolution of small bodies, as emphasized in the Planetary Science Decadal Survey, and will inform methods for deflection or disruption of hazardous near-Earth objects (NEOs). Penetrating radar can image icy comets [Sava et al 2015] but does not work well on conductive rocky asteroids. Seismology is effective for imaging the interiors of rocky and icy objects alike, with high resolution and accuracy, and is used widely in terrestrial exploration and global geophysics. However, seismology is limited in robotic space missions because it requires sensitive instruments to be deployed and anchored on the surface. The SEIS instrument on the inSight mission will record the general seismic activity of Mars as a single, complex, ground-coupled instrument, but it cannot provide the necessary coverage for 3D interior seismic imaging of the planet. On a small body the problem is worse, since no mission has ever landed and anchored to a comet or asteroid. Arrays of seismic landers are possible, but at high cost, risk, and complexity. We advocate seismic sensing using laser vibrometers [Donges & Noll 2015]. This technique is used in industrial non-destructive testing to detect minute oscillations with high bandwidth and accuracy, and with no direct contact with the studied object. At a comet or asteroid, LVs can function as remote-sensing seismometers with the following advantages: - measure vibration from a distance: no landers and anchors required; - have no data ambiguity associated with lander-surface coupling; - are robust, proven instruments with no complicated mechanical components; - can characterize ground oscillations at many distributed locations; - the stable platform in orbit is not affected by ground noise and microgravity. The proposed instrument definition study has three broad objectives: 1. Develop specifications for an orbital LV seismometer usable around a small body: (a) define laser power requirements for comet and asteroid optical reflectivities; (b) specify lens geometry to achieve small laser spots on the surface from different orbital radii; (c) design orbital conops strategies with sufficient observation time at each survey location. [PI Sava & CoI Asphaug] 2. Adapt 3D seismic imaging to LV seismic data: (a) simulate full wavefields consistent with orbital LV acquisition; (b) develop methods for LV seismic imaging for passive (e.g. tidal dissipation; thermal cracking; nucleus venting) or active sources; (c) correct for laser beam orientation relative to the target surface; (d) acquire multicomponent seismic data with LVs at different vantage points (multiple spacecraft). [PI Sava] 3. Demonstrate LV seismology on a small body subject to passive or active

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Organizational Responsibility

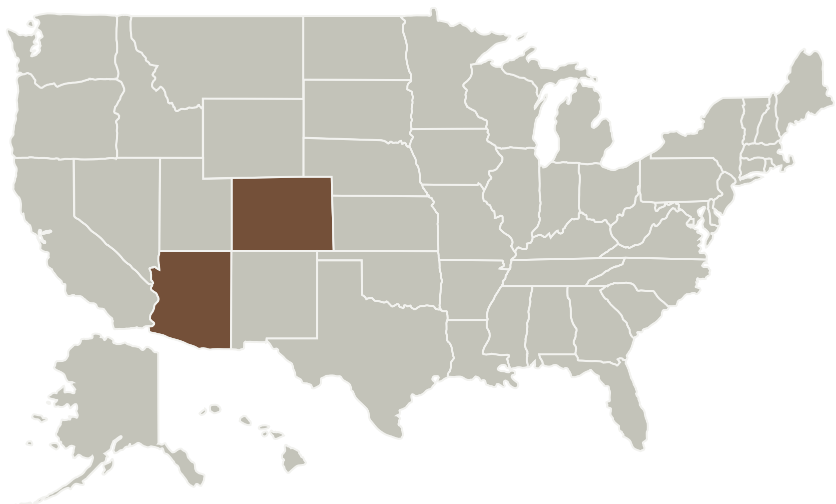
Responsible Mission Directorate:

Science Mission Directorate (SMD)

Responsible Program:

Planetary Instrument Concepts for the Advancement of Solar System Observations sources: (a) build realistic internal model structures for Phobos and 67P/C-G as type examples; (b) evaluate optimal acquisition and processing parameters; (c) quantify the attainable resolution and required mission duration. [CoI Asphaug & PI Sava] The proposed SOLVE instrument will be usable for any mission to a small body under the Discovery or New Frontiers programs. This PICASSO project will bring the SOLVE TRL from 2 to 3, resulting in a fully-defined instrument and data processing flow, to be further developed in a MAtISSE funded project.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Trustees of the Colorado School of Mines	Supporting Organization	Academia	Golden, Colorado

Primary U.S. Work Locations	
Arizona	Colorado

Project Management

Program Director:
Carolyn R Mercer

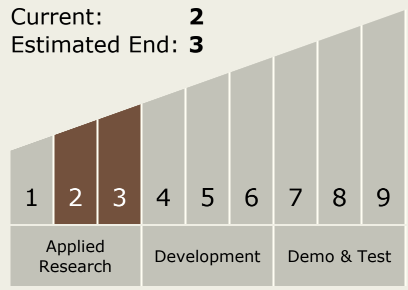
Program Manager:
Haris Riris

Principal Investigator:
Paul C Sava

Co-Investigators:
Jill Bremer
Erik Asphaug

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX08 Sensors and Instruments
  └ TX08.1 Remote Sensing Instruments/Sensors
    └ TX08.1.5 Lasers

Target Destination

Others Inside the Solar System